

Advanced Accelerator Applications Technical Quarterly Review

(Covering January-June 2002)

Transmutation Science--University Support
WBS 1.27

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July 10, 2002

Universities Working for Transmutation Sciences

- **University of Michigan**
 - Reactor/transmutation Studies
 - Irradiation experiments
- **University of California—Berkeley**
 - Reactor/transmutation Studies
 - Code development and benchmarking
- **University of Texas—Austin**
 - Proliferation Resistance
 - Spallation Product Yield Measurements
- **North Carolina State University**
 - CINC radiation effects

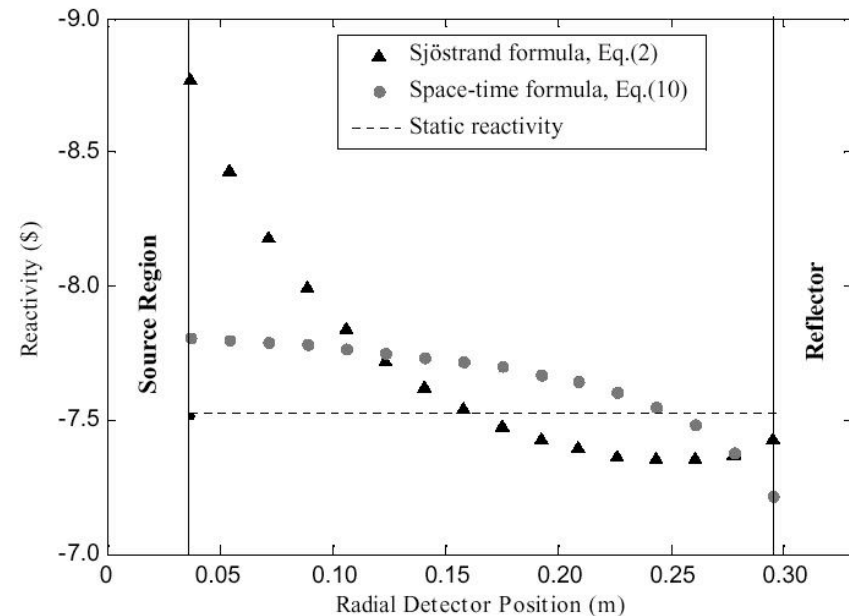
University of Michigan Progress Jan-Jun

- **Reactivity Measurement & Control studies**
- **Reactor/transmutation Studies**
- **Irradiation experiments**
- **Experiment support**

University of Michigan

Reactivity Measurement & Control

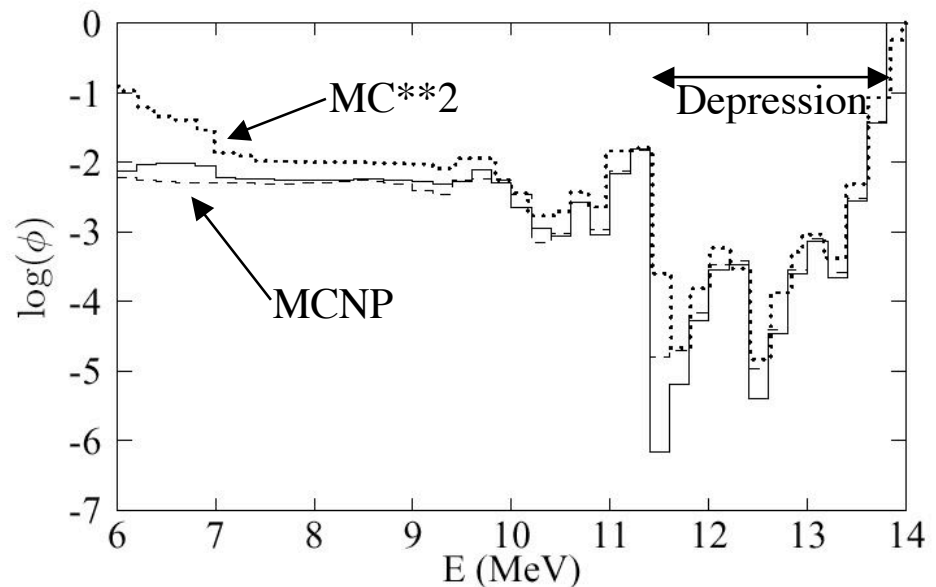
- Space-time corrected area-ratio (Sjöstrand) method developed to measure reactivity in source driven system
- Requires computed shape function and prompt neutron lifetime
- Predicted reactivity insensitive to detector placement and shape function computation



University of Michigan

Slowing down spectrum & cross sections

- Spectrum due to 14 MeV neutrons slowing down in Pb shows deep flux depression between 11.6 and 14 MeV
- Produced by non-elastic effects
- MC**2 fast-spectrum code successfully recovers essential features of this depression
- MC**2 spectrum deviates from MCNP at lower energy – due to (n,2n) cross section



University of Michigan

LWR-Based Transmutation Studies

- Equilibrium cycles generated for homogeneous and heterogeneous loadings.
- Heterogeneous results compare well with CORAIL concept.
- Heterogeneous loading leads to somewhat lower Pu inventory (4/5) than homogeneous.
- Both loadings produce zero net change in Pu inventory at equilibrium.

Recycle 40 (quasi-equilibrium)				
Fuel Content	Heterogeneous		Homogeneous	
^{235}U (wt%) ^a	4.00		3.97	
Pu (wt%) ^b	12.42		15.00	
Fissile Pu (wt%)	39.70		40.97	
Element	BOC	□	BOC	□
U	519.0	-26.6	515.0	-26.8
Np	0.0	0.3	0.0	0.3
Pu	16.1	0.0	20.0	0.0
Am	0.0	1.2	0.0	1.5
Cm	0.0	0.4	0.0	0.3
Total TRU	16.1	1.9	20.0	2.1
Total HM	535.1	-24.7	535.1	-24.7

University of Michigan HT-9 & T-91 Materials Irradiations

- **Alloy HT-9 and T-91 stock was received, machined into irradiation bars and shipped to UM**
- **Samples were pre-injected with 100 appm He at room temperature to simulate He production under irradiation.**
- **First irradiation to 3 doses between 3 and 10 dpa at 450°C scheduled to begin in July, 2002.**
- **Hardness and micro-structural analysis to follow**

University of Michigan Plans through Sep '02

- **Analysis of Coupled Accelerator Core Dynamics**
 - Perform realistic tests of the space-time reactivity formulation for pulsed source experiments presented in the summary for the Fall ANS Conference
 - Study the applicability of the space-time pulsed-source formulation for detector signals obtained in the reflector region.
- **LWR Based Reactor Transmutation Study**
 - Study multi-recycling of plutonium that allows for the depletion of Pu from spent fuel stockpile, not merely recycling of self-generated Pu.
 - Study multi-recycling of Pu+Np and eventually entire transuranics in an equilibrium cycle configuration.

University of Michigan

Plans through Sep '02 (cont'd)

- **LBE Slowing Down Spectrum Analysis**
 - Study numerical fidelity of spectral analysis options in the MC2 fast spectrum code
 - Evaluate the adequacy of neutron cross sections, especially (n,2n) cross sections, in the mid-MeV range and below.
- **AAA Target Irradiation Experiments**
 - Participate in the AAA target irradiation experiments at LANSCE
 - Analyze the July 2002 irradiation data for spectral indices and other key attributes and compare with MCNPX simulations
- **HT-9 and T-91 Material Irradiations**
 - First irradiation of HT-9 and T-91 samples to 3 doses between 3 and 10 dpa at 450°C scheduled to begin in July, 2002.
 - Hardness and microstructural analysis will be performed following the irradiation.

University of Michigan

Proposed for FY03

- **Develop Coupled Accelerator Core Dynamics Model (\$75K)**
 - Develop a coupled modal-local space-time kinetics model
 - Study stability and control issues for ADS systems
- **Compare LWR and LMR Transmutation Systems (\$60K)**
 - Perform equilibrium cycle comparison thermal and fast reactors
 - Compare fuel configurations with varying TRU compositions.
- **Develop Multi-Objective Global Fuel Cycle Analysis Methodology (\$75K)**
 - LWR equilibrium cycle methodology with the CASMO assembly-level lattice physics code and the REBUS fuel cycle code
 - Develop a global fuel cycling methodology accounting optimally for waste disposal and non-proliferation objectives
- **Spallation Neutron Material Irradiations (\$75K)**
 - Irradiate corrosion coupons and perform microstructure and micro-chemical analysis of irradiated samples
 - Broaden dose, temperature, and alloy conditions and plan for future irradiations

UC-Berkeley

Progress Jan-Jun

- Completed the Optimization of Molten Salt ATW NaF-ZrF₄ (see next viewgraph)
- Developed WACOM, simplified code to analyze multi-cycle transmutation systems
- Benchmarked MOCUP code (UCB) for core design and analysis against the DIF3D/REBUS3 code (KAERI and ANL)

An illustration of a MSR -- an interesting option for Tier 1 transmuter

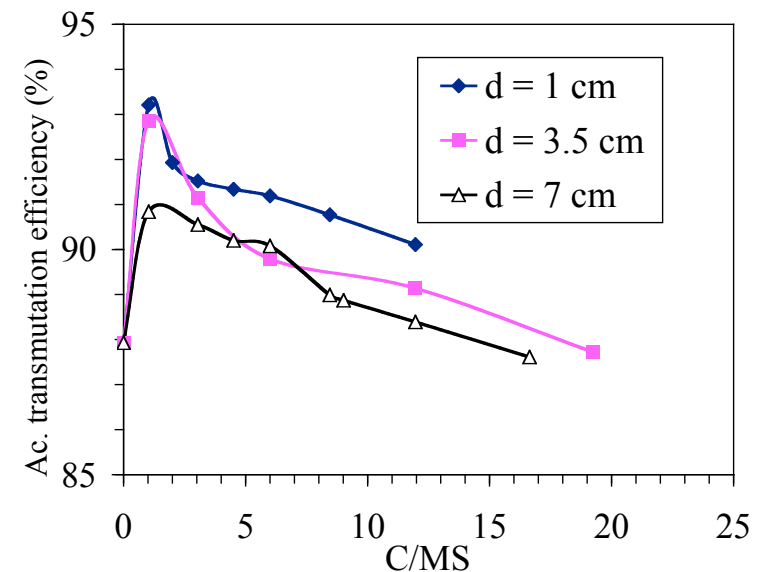
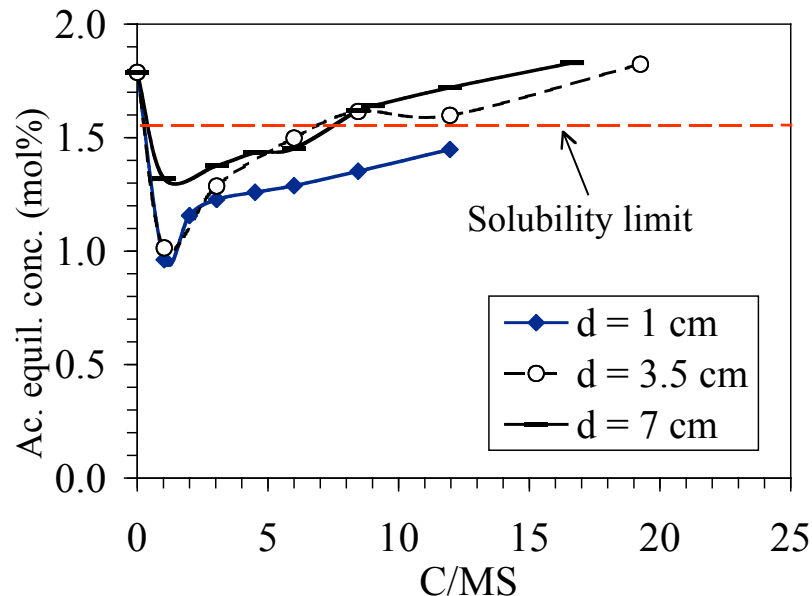
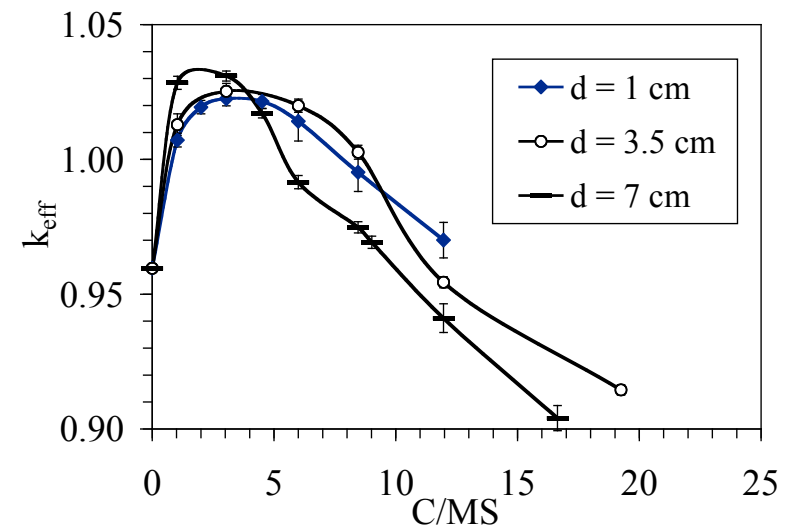
Fuel feed	TRU from LWR spent fuel
Mode of operation	Continuous feed; once through
Average power density	390 W/cm ³ of molten salt
MS channel diameter	7 cm
C/MS volume ratio	3
Fractional transmutation	90%
Total power	10,000 MW _t
k _{eff} w/o fission products	1.0
k _{eff} with removal of FP	0.99^(a) ; stays constant (equilibrium)
Accelerator power	As for 2GW _t ATW with k _{eff} (min)=0.95
Graphite lifetime	15 months
Possible scenario	Use one accelerator and one BOP to serve two MSR cores; one operating and one changing C.
Question	Is it possible to clean graphite sufficiently well from actinides and fission products?

^(a)An Estimate. Xe is removed immediately; max. Sm $\Delta k_{\text{eff}} < 0.4\%$

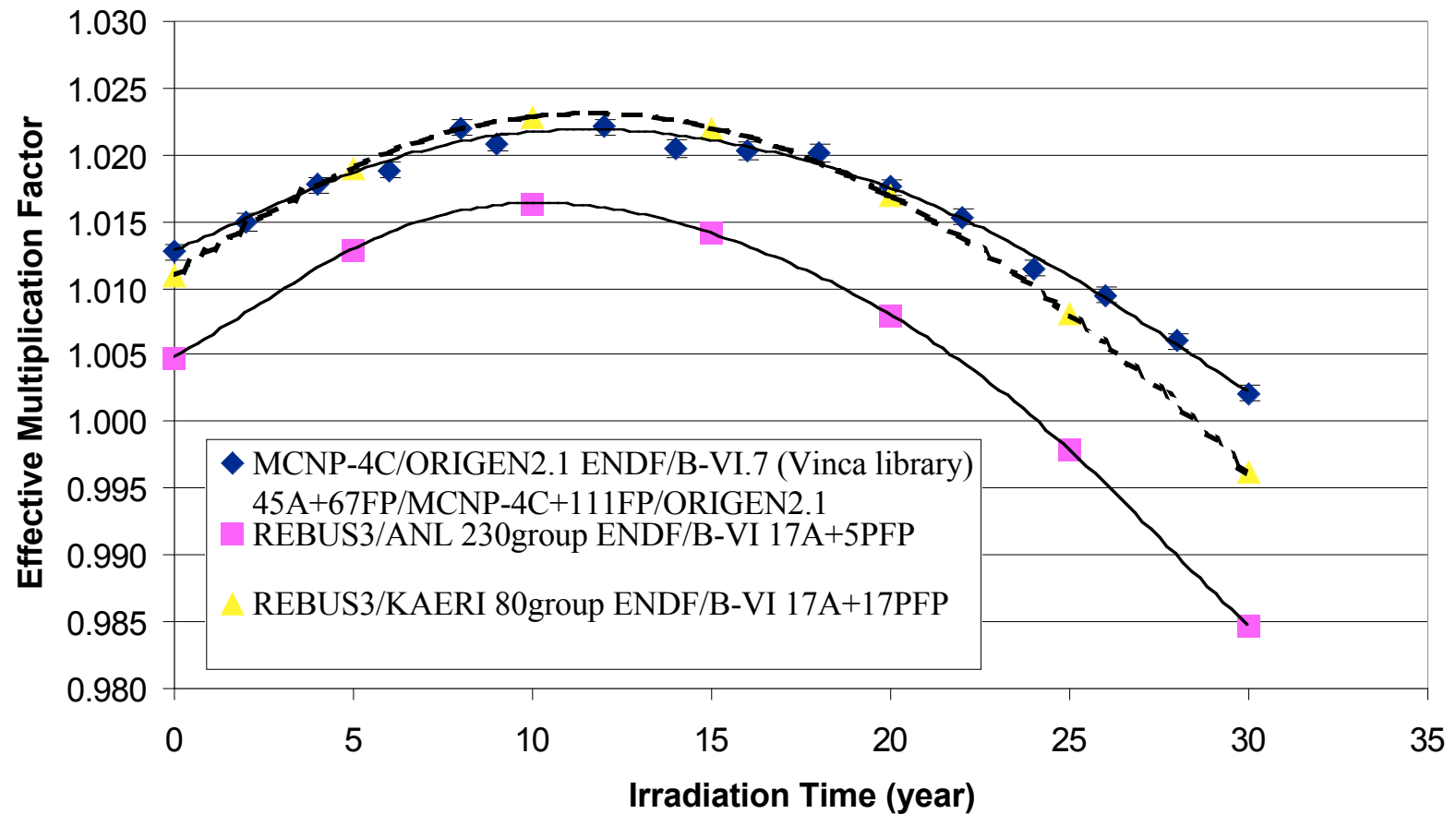
Epithermal MS Reactors are promising transmuters with Carbon to Molten Salt ratio (C/MS) of about 1 to 3

Radial leakage will reduce k_{eff} by 1-2%. Fission Products will also reduce k_{eff}

- It is possible to design MSR to have $k_{\text{eff}}(\text{equilibrium}) \sim 0.98$ without exceeding solubility limit.
 k_{eff} stays constant with time.
- Optimal C/MS $\sim 1 - 3$
- Fractional transmutation in one pass $> 90\%$
- Graphite lifetime ~ 15 months (C/MS = 3)
- Average core power density $\sim 100 \text{ W/cm}^3$ (vs. ~ 10 HTGR)



k_{eff} evolution in benchmark study of critical Pb-Bi cooled core (results of various code systems using ENDF-B/VI-based cross sections)



UC-Berkeley

Plans through Sep '02

- **Study approach to equilibrium in the MS transmuting reactor**
- **Study feasibility of MS transmuters based on LiF-BeF_2 salt**
- **Develop algorithm to account for variation of effective one group cross section and leakage probability with HM loading for the simplified fuel cycle model**
- **Complete the comparison of Na vs. LBE cooled ATW**
- **Assess transmutation capability of pebble-bed ATW**

UC-Berkeley

Proposed for FY03

- **Transmutation Studies (\$175k)**
 - Study effect of fission products on MS transmuting reactor performance
 - Work out a conceptual design of a reference MS transmuting reactor
 - Study feasibility of MS reactors as Tier-2 transmuters
 - Complete assessing the transmutation capability of pebble-bed ATW
 - Study the feasibility of transmutation in liquid-metal-cooled reactors while maintaining constant k_{eff}
- **Repository Performance (\$90k)**
 - Inter-compare waste inventory and toxicity from different transmutation systems, as measured by repository performance criteria

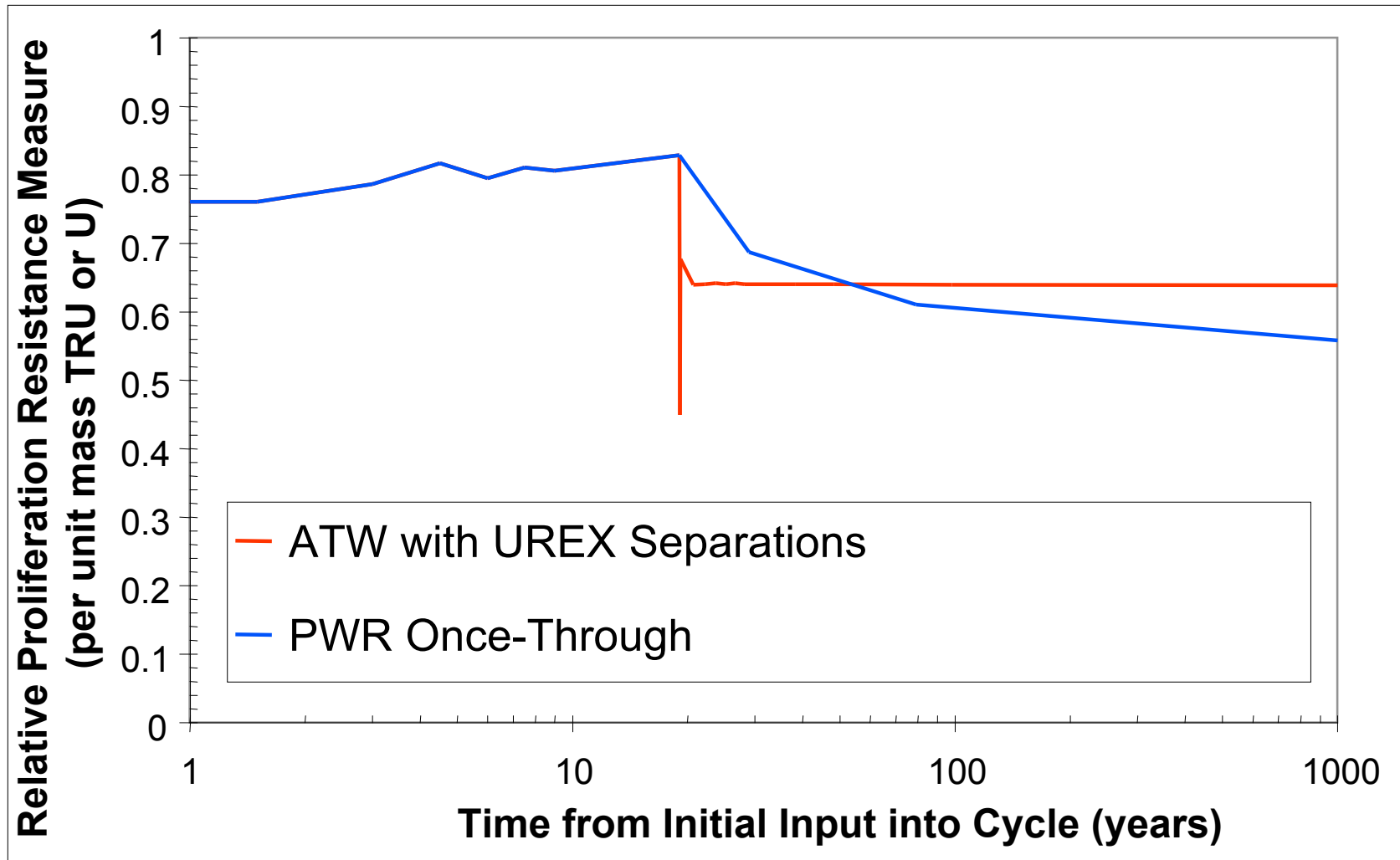
UT-Austin

Progress Jan-Jun

- **Proliferation Resistance Assessment methodology with time-dependence has been completed**
 - this uses detailed input data and weighting factors from 24 experts
 - has been applied to four long term nuclear fuel systems
 - results for two systems of interest to AAA are shown in following plot
- **The methodology has been fully documented**
 - Nuclear Technology paper detailing the methodology and results has been produced and will be submitted for publication soon (likely in July)
- **AAA Fellow Coy Bryant was graduated with a M.S.**
 - thesis: “Developing Computer Models for Solvent Extraction Processes for Optimizing Flowsheets for Actinide Transmutation and Analyzing Their Technical Benefits/Liabilities and Proliferation Resistance”

UT-Austin

Proliferation resistance for two fuel cycles (draft results pending peer review)



UT-Austin Plans through Sep '02

- **Proliferation Resistance Assessments**
 - add uncertainties to methodology
 - analyze ATW cycles and options in detail
- **Spallation Product Yield Measurements**
 - New contract/work package
 - Student at LANL
 - Plan experiments at LANSCE to measure spallation product yields for several materials of interest to AAA (e.g., Na)
 - Include short-, medium-, and long-lived radionuclides in measurements and comparisons to MCNPX calculations with existing data

UT-Austin

Proposed for FY03

- **Spallation Product Yield Measurements (\$60k)**
 - conduct experiments at LANSCE to measure various spallation product yields of interest to AAA
 - » this effort is currently funded until May 2003
- **Proliferation Resistance Assessments (\$60k)**
 - integrate assessment methodology with visual coding and interface to increase usability
 - apply methodology to more cycles (including other separations techniques)
 - collect more expert data on weighting factors and “red team” methodology with LANL experts

North Carolina State University

- **Studying radiation effects on CINC Targets, Mark II and Mark III**
- **See separate presentation**

Other Plans (University Programs)

- **FY02**
 - **Finish LANL contracts with UC Berkeley, NCSU, and UT-Austin and**
 - **Finish ANL contracts with U of Michigan and MIT (not under WBS 1.27)**
 - **Add U of Illinois (Ning Li, \$60k)**
 - » **test active online corrosion probes for LBE to monitor corrosion in-situ**
 - **U of Michigan will host a University Workshop in August**
- **FY03**
 - **UC Berkeley will host a University Workshop in April 2003**
 - » **Overlap with ANS Annual Student Conference**
 - **University Consortium for Transmutation Research**

FY03 LANL Universities Budget (\$850 k) (does not necessarily match university proposals)

• University Programs management	150
• University of Michigan	
– Reactor/transmutation Studies	125
– Irradiation experiments	160
• University of California—Berkeley	
– Reactor/transmutation Studies	175
Code development and benchmarking	
• University of Texas—Austin	
– Proliferation Resistance	60
– H & He implantation experiments	60
• North Carolina State University	
– CINQ radiation effects	60
• Univ of Illinois	
– LBE corrosion probes	60